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Science Parks and Technological Innovation

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I. INTRODUCTION

Science parks have become a common phenomenon at many western universities. At the heart of the science park movement was the belief that science parks would act as nuclei of regional technical entrepreneurship. The proximity of academic and industrial research would create a climate of symbiosis where multiple synergies for innovation would be present. In this way, both academic research and industrial innovation would benefit. Recently, however, criticisms have come to attack this point of view. Geographical proximity has been overemphasized, to the detriment of professional proximity, it has been argued.

The paper starts with a brief overview of the enthusiasm surrounding the initial development of science parks. It then goes on reviewing some of the findings from the field of technology and R&D management. These findings allow for a more thorough explanation of recent criticisms on the relevance of science parks in inducing industrial innovation. Finally, the major issues emerging from the previous discussion will be illustrated through a survey of the company population on Belgian and Dutch science parks.

II. FROM ENTHUSIASM TO SCEPTICISM?

In order to keep abreast of scientific and technological developments, external sourcing of scientific and technological information becomes

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increasingly important to the modern corporation. Along with a growing awareness of this need for extra-organizational scientific and technological linkages, the belief that universities constitute a significant *underutilized* source of technological innovation has gained wide acceptance. For instance, a National Science Foundation study (1982) states that "direct links between universities and corporations currently constitute only a miniscule portion (less than one-half of one percent) of the national R&D-effort." Nonetheless, there exists a firm belief that universities could play a crucial role in promoting technological change. First of all, they make their contributions *indirectly* by advancing the frontiers of science, by critically reviewing and systematizing the accumulated technical knowledge, and, especially through the training of students and researchers.

But, at the same time, universities can be viewed as pools of technical expertise and creativity to be tapped *directly* through the involvement of academic scientists and engineers in the process of industrial innovation. Stankiewicz (1984) argues that the emphasis on such direct links is growing. Jaffe (1989) demonstrates the existence of a significant effect of university research on corporate patents in such areas as drugs, medical technology, electronics, optics, and nuclear technology. In addition, he argues that university research acts indirectly on innovation through inducing industrial R&D spending. It is not astonishing then that governments, universities as well as industry have engaged in a wide spectrum of organizational experiments aimed at strengthening the links between the academic and industrial environment.

One experiment has been the creation of science and technology parks. According to the United Kingdom Science Park Association, a Science Park is a property based initiative which includes the following features:

- has formal and operational links with a University, other Higher Education Institution or Research Center;
- is designed to encourage the formation and growth of knowledge-based businesses and other organizations normally resident on site;
- has a management function which is actively engaged in the transfer of technology and business skills to the organizations on site.(see Monck et al.,1988)).

This definition reflects the concern of universities and other technical institutions to encourage the transfer of technology and business skills among the tenants of the park. It thus excludes those instances where there is no organizational commitment to stimulate or facilitate access to technology.

It is not astonishing then that the role models provided by Silicon Valley, Boston's Route 128, and Cambridge-UK have led to numerous attempts to imitate the emergence of high-technology clusters. These success stories convinced regional development planners that a scenario existed to create regional entrepreneurial technology clusters. The local university would act as a growth pole, being a locus of high technology information to established industrial firms and, at the same time, being a source of new technology based firms. The presence of a science park would facilitate the transition of academic scientists to become academic entrepreneurs. Physical proximity would ease the flow of scientific/technological information and the creation of a network of collaborations among different science park tenants. Resident companies would gain privileged access to highly specialized manpower in the form of graduate students and university researchers. Thus, one of the *fundamental premises* in the justification for the growing number of science parks is that high-technology industry gains competitive advantage through location alongside a university because of the enhanced information, collaboration and recruitment opportunities, (see Stankiewicz (1984) and Monck et al. (1988)).

The enthusiasm of government planners, university officials and industrialists has led to the creation of numerous science parks: Engstrüm (1987) describes the existence of more than 150 US science parks; a 1988 Financial Times survey announced the presence of 38 operational parks in the UK, while 9 more were planned; Belgium nowadays has 10 university science parks; the Netherlands 3. The list is still growing and this growth is not likely to come to an end in the near future.

Notwithstanding this enthusiasm, research studies have become increasingly sceptic. The NSF-study on university-industry relationships (1982) found that over 50 percent of the US-parks never approached their initial expectations and that they are generally not significant stimuli to technology transfer. Miller and Côté reach the same conclusion in their recent book, "Growing the Next Silicon Valley" (1987). Macdonald (1987) pretends that much of the enthusiasm surrounding British science parks is a product of self-interest and is in stark contrast to the (dark) reality that will eventually face many of them. Monck et al.(1988) concluded their survey (sponsored by the

UK-Science Park Association) with the following statement: "These results suggest the need to reappraise the comparative advantage of a science park location. They indicate two alternatives. The first is that less emphasis should be placed upon direct or indirect links with the local university, since that can apparently be cultivated by firms located elsewhere. Alternatively, the results indicate that the level of university linkage developed by off-park firms has not significantly been bettered by science park firms."

III. SCIENCE PARKS: A THEORETICAL EVALUATION

A. *Interorganizational R&D-linkages*

Research on corporate technology strategy points to the increasing importance of external R&D linkages, (see Heenan (1986)),(see Fusfeld (1985) and Perlmutter and Heenan (1986). At the same time, however, Haklisch's (1986) systematic review of technical alliances in the semiconducter industry shows that such collaborations are not confined to a specific geographical context. Daly (1985) demonstrates the same world-wide network of R&D cooperations and information flows in his strategic analysis of the biotechnology industry. Thus, the explanation of science park advocates that geographical proximity will stimulate interorganizational information networks among science park occupants may be based on a biased understanding of the relation between physical distance and communication. Allen (1984) indeed demonstrates that physical distance has an overwhelming influence on *internal* corporate communications. However, his major finding is that beyond a distance of 30 metres the probability of informal information exchange reaches an asymptotic level. Thus, as far as informal, face-to-face communication is concerned, it does not matter whether you are in two separate buildings on the same science park or in two buildings 250 kilometers apart. As a further example, the worldwide membership affiliation of MIT's Industrial Liaison Program shows that geographical proximity may only be of secondary importance. This can be explained by the fact that person-to-person networks basically are of two types: spatial and professional. Spatial networks are based on a social and/or physical propinquity such as exists within the industrial research laboratories studied by Allen. Professional networks are networks such as the classical invisible college of academic science which links specialists of a particular discipline or profession and have no boundaries per se. Some professional networks are also spatial. Silicon Valley is a leading center of microchip design. With such centers one must stay in touch. Those in the same profession but located elsewhere must still be part of the spatial professional network of such centers and hence must by frequent contact maintain this membership. Geographical, or physical, proximity is not a necessary condition when task-related communications are considered. Evans et al. (1974) found that the number of communications did drop off considerably with distance, but work-related professional contacts override the distance factor. Van Dierdonck and Van der Poorten in a study of the diffusion of artificial intelligence in Belgium (1987) found frequent contacts of Belgian entrepreneurs with MIT and other Route 128 entreprises. The professional network clearly has no specific geographical boundaries. What really matters is to become part of the broader professional network.

Social proximity is yet another factor which overrides geographical proximity. Corsten (1985) found that a majority of the companies in his sample contacted a particular university because either *(1)* graduates of that particular university worked at that company (44 percent) or *(2)* company representatives knew university scientists from contacts at conferences or seminars (23 percent). Thus, one may wonder whether the justifications given for the stimulation of science parks are over-emphasizing the benefits of geographical proximity to the neglect of professional and social proximity variables. Although these three types of proximity variables can occur simultaneously, this need not be the case.

B. *The interaction between science and technology*

According to Price (1965) science and technology each have their own, separate cumulating structures. Only in special and traumatic cases involving the breaking of a paradigm, see Kuhn (1962) and Dosi (1982) can there be a direct flow from the research front of science to that of technology or vice versa. Allen (1984) basically agrees with this point of view, although he recognizes the possibility of a gap-filling science : "Occasionally, technology is forced to forfeit some of its independence. This happens when its advance is impeded by a lack of understanding of the scientific basis of the phenomena with which it is dealing. The call then goes out for help." This call for help may cause a temporary, intense interaction between science and technology. Another remark on Price's thesis is that nowadays, technologies have emerged (e.g. biotechnology, artificial intelligence) which are much more rooted into academic science. Although conflicting views exist on the intensity of the link between (academic) science and (industrial) technology, one may wonder whether advocates of science parks are overrating the degree of coupling between science and technology. This coupling is true for certain technologies, but there is no proof that it holds across all technologies. To summarize, Allen et al.'s (1980) studies of the different types of communication along the R&D activity spectrum suggest the following conclusions with respect to science parks as facilitators of R&D communications:

- *research tasks* are universal. The external world is the universal, invisible college.The nearby presence of a particular university will not be a decisive factor, except perhaps if the organization's research has particular links with a specific laboratoryof the local science park university.
- *development tasks* rely heavily on internal communications while external communications are managed by the emergence of technological gatekeepers. Moreover, locally oriented tasks such as development work) are hypothesized to benefit more from outside operational (e.g. customers and vendors) contacts than from outside professional (e.g. R&D community as a whole, professional associations) contacts.
- *technical service tasks* consist mainly of cost/benefit analyses and incremental product/process improvements. These tasks heavily rely on hierarchical management control and there is little need for external interactions. Thus, we may wonder whether much input from science-based organizations is necessary.

Moreover, when referring to the science/technology interactions occurring in Silicon Valley or along Route 128, Dorfman (1983) reminds us that "the academic institutions that provided much of the momentum are steeped in a tradition of research at the frontiers of developments in electronics, computer science and instrumentation and compete with a handful of other universities for top ranking in graduate programs in these fields. It remains to be seen whether institutions of lesser rank can provide the same stimulus to innovation."

C. *Labor supply factors*

Labor supply opportunities have often been considered a critical location factor in high-technology industry, see Oakey (1981) and Dorfman (1983). For several reasons, which are discussed below, this labor supply factor is another hypothesized advantage of the science park environment.

First of all, the symbiosis of university and industry is believed to enhance recruitment opportunities for industrial R&D. Through collaborations with academia, industry gains access to high-talented engineers and scientists. Recent studies on manpower flows in artificial intelligence, (see Van Dierdonck and Van der Poorten (1987)), and biotechnology, (see Faulkner (1986)), show the omni-presence of manpower flows between academic and industrial R&D-laboratories in nascent, science-based industries. However, when focusing on science parks, Sirbu et al. (1976) found that "virtually no interchange of personnel was reported between government laboratories and industry at any of the sites. There is a modest flow of personnel from university laboratories to industry, but very little in the reverse direction." As far as the recruitment of university graduates is concerned, those authors reached the following conclusions: "Most of the US firms we interviewed recruited on a nationwide basis and none felt they drew disproportionally from local universities. They reported hiring 16.5% of their staff on average from local schools.". Monck et al. (1988), in their study of British science parks, report similar findings. They were certainly unable to detect significant differences in recruitment patterns between off-park and on-park companies.

Second, science parks are believed to act as a catalyst for academic entrepreneurial behavior. The presence of a nurturing science park environment should facilitate researcher transitions from the safe academic world to the risky, uncertain business world. Roberts and Wainer (1968, 1971, 1988) provide us with an overwhelming data-base of MIT-entrepreneurs who clustered around Route 128. Segal et al. (1985) identified a family tree of 244 companies which directly or indirectly originated from 14 Cambridge University departments. However, when referring to those success stories, a few remarks should be kept in mind. First of all, in none of these two examples is there a clear proof that a local science park enhanced this spin-off phenomenon. Even in the case of Stanford Industrial park, not everyone agrees on its causal link to the high-tech spin-off phenomenon of Silicon Valley. Macdonald (1987) even goes as far as to argue: "While the University certainly did establish the park, it did so primarily because the industrial growth of the region had increased Leland Stanford's bequest so much that the University could no longer afford its retention as farmland. Unable to sell the land, the University was forced to make it pay for itself. Stanford Industrial Park is very much the product of Silicon Valley's industrial prosperity rather than vice versa." Second, although more and more universities acknowledge the potential of new venture creation as a technology transfer mechanism, academic entrepreneurs are still a "curiosum" at most academic institutions. Miller and Côté (1987) suggest that a majority of science parks have not been able to stimulate massive spin-off creation. To summarize, although it may be advantageous to an academic spin-off to locate on a science park (since the entrepreneurs then remain close to their nucleus) the extent as to which this happens in reality is rather ambiguous. Monck et al.'s (1988) study of British science parks suggests a similar ambiguity.

Third, it is often argued that proximity to a university offers opportunities for continuing education of company staff. Participation in such programs on behalf of science park tenants might offer a first step in forging more intense links between organizations on the park (including the university). This might then overcome some of the scepticisms described earlier. Indeed, it is often argued that informal linkages are a first and a highly necessary step in establishing more formalized R&D collaborations, see Stankiewicz (1984) and Faulkner (1986): participation in continuing education programs may thus influence the social proximity factor discussed earlier. However, even when a technical/social network of contacts among science park occupants should occur, Macdonald (1987) suggests that it will only be a "miniature network" in comparison to the global scientific and technological network relevant to the different science park tenants.

D. *Advantages to regional development*

Regional development policies also had a major impact on the decision to create university science parks. For instance, Japanese science parks were not so much developed to foster interorganizational collaborations as to decrease the pressure on already heavily industrialized areas like Yokohama, Osaka, Kobe and Kyoto.

Dorfman (1983) further refers to agglomeration externalities as another advantage of a high-technology cluster location. For some firms in some industries and at some stages of development there are indeed important advantages to locate near to complementary and competitive enterprises as well as to customers. Segal et al. (1985) reach the same conclusion in their study of the Cambridge Phenomenon. However, when considering Silicon Valley, Route 128 or the Cambridge Phenomenon, we are confronted with phenomena involving a region's (multiple) universities. Typically, the new high-tech businesses became embedded in an existing business and technological infrastructure in a rather spontaneous manner. Most European (and American) science parks, on the contrary, are rather artificially created around a single university which is then believed to act as a growth pole. They are often isolated, with little or no local business texture present. Segal et al. clearly demonstrated the role of the inner Cambridge town in the growth of the Cambridge high-tech cluster. For the majority of science parks, it is rather difficult to speak of external economies of scale. At best, one can hope that they will evolve over a longer period of time. Thus, the advantages offered by the 'rich business environment on the park' (Monck, 1983) may well be an illusion at present.

Finally, environmental factors such as attractive parkland surroundings, residential neighbourhoods, cultural amenities, and easy access to transportation seem to be important only up to a certain treshold level (see Sirbu et al.(1976) and Galbraith (1985) and Monck et al. (1988)).

E. *The need for empirical investigation*

The previous discussion focused on a number of general issues facing the development of university science parks as they appear from the literature. The next section of the paper will investigate a number of those issues for the firms located on Belgian and Dutch science parks. This will enable us to assess the situation in Belgium and the Netherlands in particular, since the literature is rather general in nature and intercountry differences among science parks may account for the fact that the findings from the literature have limited external validity.

IV. SURVEY OF BELGIAN AND DUTCH SCIENCE PARK TENANTS

This section starts with a brief description of the sample characteristics before focusing on the major issues as they appeared from the literature survey.

A. *The sample*

At the moment of the survey (fall 1988), 8 Belgian and 3 Dutch science parks were fully operational. All of them became possible through government intervention. Regional Development Agencies are heavily involved in the exploitation of the parks. The role of most universities is at least a consultative one. They all assist in the screening of candidate applications, while their involvement in the daily management of the science park varies.

TABLE 1

Sample and response rate

Sites	First year of operations	Sample N	Valid responses
Belgium			
Haasrode	1972-73	32	16 (50%)
Sart-Tilman	1976	23	8 (35%)
Louvain (LLN)	1976	34	20 (59%)
Evere	1978	28	11 (39%)
Heembeek	1980	7	6 (86%)
Anderlecht	1985	1	1(100%)
Nivelles	1985	2	2(100%)
Zellik	1985	10	4 (40%)
Total		137	68 (50%)
Netherlands			
Twente	1983	49	29 (59%)
Groningen	1984	9	5 (56%)
Leiden	1985	13	7 (54%)
Total		71	41 (58%)

Each science park is linked to a single university. Some universities can have up to 3 affiliated science parks. Some of the parks are adjacent to the university, others are up to 15 kilometers distant from the patronizing academic institution. Half of the science parks in the sample are less than 5 years old (Table 1). Of course, the age of most science parks may be a biasing factor in surveys investigating this phenomenon. Indeed, science park advocates claim that it may take at least a decade for a cluster to be formed. For instance, strong useful links between academia and industry develop over many years through the gradual growth of experience and trust among individuals. However, the results of this and other (see Sirbu et al. (1976) and Monck et al. (1988)) surveys can at least provide some impressions of the science park potential. Moreover, there exist at the moment several science parks which are more than a decade old. This makes some predictions even less ambiguous.

In the Belgian case, 15 science park tenants were not included in the sample because of their activities (hotel, garage, tennis court, university laboratories, etc.). Thus, we were only interested in companies which might somehow benefit from interactions with academia or other high-tech firms. In the course of the survey, we learned that 7 of the 137 Belgian companies had left the science park in 1988. This reduced the Belgian subset from 75 to 68 useful responses, since the companies who left the science park did not fill out the questionnaire. Most of them declared that the science park location had only been a temporary solution to them and thus showed a rather low commitment towards the local science park environment. As far as the Netherlands are concerned, Twente is somewhat different from the other science parks. This science park is in fact an incubator facility: the Business Technology Center. It was established through the involvement of Control Data, a Regional Development Agency and the University of Twente. Sunman (1986) ascribes the rapid growth of BTC Twente to the commercial orientation of its founders (especially Control Data). According to the definition of the UK-Science Park Association, BTC can be considered as a science park development. However, the emphasis on being an incubator may introduce a bias in the Dutch results (e.g., companies in the incubator will usually be small). However, BTC equally stresses the importance of its scientific/technological environment to potential candidates.

The questionnaires were mailed out to the general managers of the science park companies. All returned questionnaires were eventually filled out by senior managers. Thus, we can be confident that the respondents had a broad view on the companies' activities as well as on the decision to locate on the site. The results then offer a first impression of what happens on Belgian and Dutch science parks.

B. *Company characteristics*

This section describes the characteristics of the respondent firms. After discussing the age and employment characteristics of the tenants, we investigate how many tenants belong to a multinational group for both countries. As one important objective of many science parks is to stimulate entrepreneurial behavior, we were particularly interested in the presence of spin-off companies on the science parks studied. We defined a spin-off as "A company created by employees who leave their employer (e.g. a university laboratory, an industrial laboratory) to start their proper firm in order to commercialize technological know-how acquired on their previous job."

As could be expected, the presence of the majority of respondents on each site studied is rather recent (see Table 2)

TABLE 2

Age characteristics of responding tenant firms (mean age, median age and age range)

	Mean	Median	Range
Belgium (n = 67)	31/2	2	0-12
Netherlands (n = 40)	21/3	2	0-6

Thus, although 4 Belgian science parks were created in the 1970's, their growth really started in the 80's. Only 10 respondents were established between 1976 and 1979. The take-off of Dutch science parks was much faster than in the Belgian case. The role of BTC Twente, which accounts for the majority of the Dutch sample and the Dutch respondents, is obvious. The other Dutch sites may develop more at the rate of their Belgian counterparts. Although Belgium showed considerable enthusiasm in the early 70's, there has been a period of stagnation between 1977 and 1985. Since 1985, the interest of regional developers and universities seems to be increasing once again. The number of new tenants on Belgian sites may reflect this policy change (median age = 2 years).

Total employment for the Belgian respondents (n = 68) amounts to 3856. In the Dutch case this figure is 480 (n = 41). In both instances, the majority of tenants is small (see Table 3). Belgian science parks, however, were able to attract some major multinational companies (mainly in the sphere of electronics, informatics, and pharmaceuticals). Blue collar workers are a minority among science park employees. This is obvious since all science parks formally 'forbid' traditional manufacturing activities. As we will see, a lot of respondents actually have production facilities, though, in terms of employment, these activities are of secondary importance. Science park authorities also appear to be rather flexible with respect to the application of the admission rules. In some instances, the policies of regional developers have aroused irritation on the academic side. Regional Development Agencies have sometimes been accused of attaching too much importance to employment statistics, to the neglect of the creation of a technology-oriented business texture.

A total of 9 companies on Dutch science parks (n = 41, 22%) belong to a multinational group. This number is much higher in Belgium: 33 out of 68 tenants (49%). This is reflective of the policy of Belgian science park authorities to attract foreign investments, whereas Dutch science parks are more geared towards stimulating indigeneous growth. This is further exemplified by the presence of spin-offs on the science parks studied. In the Dutch case, 15 out of 41 (37%) respondents acknowledged to be a spin-off. Six of them originated from a local university laboratory, two from another science park organization. The remaining 7 had no such relationship with other science park tenants. In Belgium, only 11 (n = 68, 16%) spin-offs were detected among the respondents. Two of them originated from the local science park university. In the remaining cases, no apparent links with another science park 'parent' were found. From those results, one may conclude that Belgian science parks have not been significant spin-off generators till now. This does not mean that academic spin-offs are absent in Belgium. We were able to detect the existence of at least 42 spin-offs at Belgian universities, see Van Dierdonck and Debackere (1988). The majority of them were less than 5 years old. Only, they do not seem to have a preference for a science park location. One should also recognize that the Belgian academic community has long been, and in some cases still is, sceptical towards academic entrepreneurs. Moreover, not all scientists display the same degree of entrepreneurial behavior, see Roberts and Peters (1981) and McMullan and Melnyk (1988). The difference between Belgium and the Netherlands concerning spin-offs may also be a reflection of the different

TABLE 3

Employment characteristics of responding tenants

	Belgium (n=68)	Netherlands (n=41)
Total employment		
Mean	56,7	11,7
Median	23,5	4
Range	0-380	0-50
Blue collar employment		
Mean	5,4	1,7
Median	0	0
Range	0-50	0-30

degree of involvement on behalf of the parent university in the management of the science park. Although regional developers play a crucial role in both countries, Dutch universities pursue their consultative role in a much more active manner. In Belgium only one university has been really actively involved in the promotion and management of its science park from the very beginning. Other universities have started following this example now, after they were rather passive in the past. Although it is dangerous to make causal inferences, it appears as if active university involvement (preferably beyond a consultative role) exerts a positive influence on the development of the science park.

Only a minority of respondents provided financial results. Some of them were unable to do so for various reasons (establishment on the site too recent; being part of a larger industrial group makes it impossible to sort out the results of the science park entity; the activities of the tenant are not profit-oriented), while others were simply unwilling to provide financial information. For those who did provide financial results, we can only say that the figures provided reflect the small-sized nature of the businesses present on most science parks.

C. *Company activities*

The broad range of activities undertaken by the respondents in this survey makes it hard to categorize them. In an attempt at classification, Table 4 presents 7 main categories. In classifying firms in this way, it must be remembered that the same firm may undertake a number of activities at the particular location and that it can, in some cases, be difficult to identify a single main activity. This classification should, then, only be taken as broadly indicative of the activities of the surveyed firms.

TABLE 4

Respondents' activities

	Belgium (n=68)	Netherlands (n=41)
Electronics and data processing equipment	12	4
Medicine, biotechnology and pharmaceuticals	8	7
Telecommunications	4	2
Informatics	7	6
Consultancy	10	14
Teaching and training	5	1
Other	22	7

Those activities are not only very diverse. At the level of the individual science parks, they even do not always match with the university's specialization. So there is the example of a university which has a good reputation in biotechnology, while the majority of firms on its science park are well established micro-electronics firms. Moreover, the broad range of activities present on each park makes one wonder at the effectiveness of science parks in creating an atmosphere where ideas flow freely among researchers at different organizations present on the park. It is our belief that openness is indeed beneficial to technology development. However, this openness should prevail within the community of researchers working on a certain related set of scientific and technological problems. This R&D community is, however, not confined to the narrow geographic boundaries of a science park. Instead, it is a global phenomenon. The local environment on the science park is at best a miniscule node in the communication and collaboration network relevant to each researcher. The diversity of activities present on most science parks certainly questions their potential in bringing together a critical mass of researchers on one particular spot.

Finally, each respondent described the different functional activities present at his company: 13 Dutch respondents (32%) and 39 Belgian respondents (57%) reported internal R&D activities. However, the absence of internal R&D does not prevent companies from having contacts and even research contracts with the local university (cfr. infra). Small companies may actually use the local university as a kind of external R&D department. Moreover, 24 Dutch respondents (59%) and 44 Belgian respondents (65%) had marketing activities at the site, while 19 Dutch respondents (46%) and 34 Belgian respondents (50%) had production activities at the site. The presence of production activities in nearly half of the companies surveyed, and the absence of internal R&D in about half of the companies surveyed, are rather striking findings if one keeps in mind the missions of a science park.

D. *Reasons to locate on the park*

Respondents were asked to rank-order the three most important reasons for their choice to locate on the site. It is somewhat surprising that 20 Dutch (49%) and 35 Belgian (51%) do not mention the availability of external scientific/technological resources at all when discussing their location decision. About half of the survey respondents do not perceive the linkage potential with the local university and/or other high-tech neighbours an important factor in their location decision. Table 5 shows that only a minority of respondents mention such factors as crucial decision variables.

TABLE 5

External scientific and technological resources as factors influencing loaction decision

Availability of scientific/ technological resources rank-ordered as...	Belgium(n = 68)	Netherlands(n = 41)
1st most important	7	8
2nd most important	14	9
3rd most important	12	4

Other factors influencing the location decision were: image of the site, easy access to highways or airports, financial incentives by public agencies (tax deductions, subventions), convenience of the site, available office space and services provided to young entrepreneurs (BTC Twente, Incubator Facility Leuven), etc. Only one respondent explicitly stated that recruitment opportunities were a motivating factor. Quite similar to the Monck et al.'s (1988) finding for the British situation, "it was the prestige and image of the site which was the most frequently mentioned factor influencing choice of location".

E. *Interorganizational linkages among respondent*

1. Contacts with the local university

A total of 34 (83%) Dutch respondents and 46 (68%) Belgian respondents confirmed the existence of contacts with the local university. Table 6 summarizes the types of linkages. Each respondent could check more than one category.

TABLE 6

Number of respondents per type of linkage

Type of linkage	Belgium (n=68)	Netherlands (n=41)
Collaborative R&D	17	12
Academic consulting	14	12
Service (e.g. routine tests and analyses)	8	4
Informal contacts	18	16
Other	12	12

As already mentioned, tenants do not need internal R&D capabilities to become involved in cooperations with the local university. For instance, only 7 out of 12 Dutch tenants involved in collaborative R&D with the local university have in-house R&D-capabilities. Thus, 5 Dutch respondents (see Table 6) without internal R&D do have collaborative R&D with the local university.

Other linkages include such activities as: organizing seminars together with a university department; the founder of the company was a student or researcher at the university; the company is a university supplier (e.g. medical equipment); key scientists of the tenant lecture at the university; the tenant supports the university's computer facilities etc. In many of those instances, the university benefits more from the presence of the tenant company than vice versa. This finding was also reported by Sirbu et al. (1976).

To conclude, although a majority of respondents has some type of linkage with the local university, only a minority of these linkages involves collaborative R&D. Our research at this phase was only intended to get an overall impression of the R&D environment on Belgian and Dutch science parks, and, as a consequence, did not include a control group of off-park firms. Nevertheless, it is interesting to quote Monck et al.'s (1988) results here: "The most obvious and perhaps surprising observation is how apparently similar off-park firms' responses were to those of on-park firms. This is particularly clear in the R&D and personnel links. Park-based firms clearly place a greater emphasis on informal contacts with academics. In the more formal links such as the employment of academics, sponsoring trials, student project links and the employment of graduates, off-park firms have an equal or greater number of links."

2. Labor supply

Labor supply was one of the critical factors in the Dorfman study (1983). Table 7 summarizes the number of local university graduates employed at the respondents' facilities.

TABLE 7

Employment of local university graduates

Number of local university graduates employed	Belgium (n=68)	Netherlands (n=41)
0	35	24
1-5	25	15
6-10	2	2
11-15	4	0
20	1	0
30	1	0

The total number of local university graduates employed at Belgian respondents is 179 (total employment=3856). In the Dutch case we find 61 local university graduates (total employment = 480). Given the scope of this preliminary survey, comparison with off-park firms is impossible. We also lack information on the relative number of graduates from other universities employed at the respondents. This makes interpretation of Table 7 a bit ambiguous. However, the fact that more than half of the respondents do not employ local university graduates at all questions the importance of the labor supply factor within the micro-environmant of the parks. This finding confirms Sirbu's (1976) suggestion that science park tenants recruit on a nation-wide basis.

Another potential advantage of a science park location is the easy access of tenants' employees to continuing education programs at the local university. Ten Dutch respondents (24%) and 18 Belgian respondents (26%) acknowledge to make use of this opportunity. This situation may well be subject to change in coming years as more and more universities start offering post-experience courses. However, at the moment, continuing education appears to be a rather limited phenomenon. Moreover, in many instances it is confined to employees enrolling in management and business oriented courses at the nearby university.

3. R&D projects

The 13 Dutch and 39 Belgian respondents who mentioned the presence of internal R&D capabilities, also specified the actual number of R&D projects in progress, the fraction of those projects carried out without external collaboration, and the distribution of projects involving external partners. Table 8 summarizes some of the results.

TABLE 8

Number of internal/external R&D projects at respondents having internal R&D capabilities

	Belgium (n=39)	Netherlands (n=13)
Total number of projects in progress	321	65
Fraction not involving external partners	168(52%)	25(38%)
Fraction involving external partners	153(48%)	40(62%)
- local university as partner	35	12
- other science park partner	3	2

Although formal, external R&D linkages are important, they are not really biased towards the local science park environment. In Belgium, 38 (out of 153, 25%) R&D projects were directed towards local science park organizations. For the Dutch respondents, this amounted to to 35%, or 14 projects. Of course, this does not yet tell us very much about the characteristics of the projects (content, duration, degree of innovativeness, etc.). But we must not forget that over half of our respondents did not have internal R&D-activities. We are confident that the respondents without internal R&D who are involved in collaborative projects together with the local university will not alter the obtained percentages much. We arrive at this assumption by looking at the individual respondents. The respondents in Table 8 are without doubt the most important R&D-oriented tenants on the sites studied. The respondents who have no internal R&D capabilities, though are involved with the local university, are all very small and production or marketing oriented.

Table 8 also demonstrates that collaborative R&D efforts are not confined to a physical locus. The collaborative R&D-efforts reported in Table 8 do not only have a national dimension (as well in Belgium as in the Netherlands, a lot of respondents having collaborations with the local university also have collaborations with a major part of the nations' other universities), but they take on international dimensions as well (e.g. projects together with other European and even U.S. universities).

The small firms reporting collaborative R&D have a strong bias towards the local university. Thus, this type of company might actually gain easier access to the R&D community by locating near a particular university. But even here, Macdonald (1987) warns us :" The notion that any single university department contains even all the technical information required by a high-technology firm, while evident in much of the justification given for science parks, would alarm most academics. Only a weak department can pretend to be self-contained : the strongest department is more likely to be but a node of an academic information network to which high-technology firms may seek access."

V. CONCLUSION

This discussion was a first attempt at providing some insight into the potential role of science parks in the process of technological innovation. It was argued that we should at least be offered some empirical insight into potential advantages and misconceptions related to this new development, since the number of science parks keeps growing and since those science parks are often claimed to offer a competitive advantage to tenant firms in terms of access to the R&D community. One key conclusion is that a science park location may indeed ease access to a single university, although our findings and the findings of similar foreign studies question the degree to which this really happens. Moreover, the university affiliated with the science park is at best one node in the global R&D community of interest to the high-technology firm. Scientific and technological developments occur within the context of broader R&D communities. Such communities are global in nature, encompassing researchers in organizations in the private as well as in the public sector. Macdonald's warning that a science park can create at most a "miniature network" among tenants is highly relevant in this respect and seems to be borne out by our findings on collaborative R&D at science park firms.

This leads to another remark. Given the ambiguous performance of most science parks, we believe it is time for a clear assessment of their mission. Our findings on some of the older Belgian parks clearly demonstrate that they have been successful in attracting tenant firms. However, in terms of fostering extra-organizational R&D linkages the situation looks a little different. There do exist linkages towards the local science park environment, though they are rather sparse. Nowadays, each university believes an affiliated science park is an absolute necessity in order to become an accepted player in the newly emerging arena of entrepreneurial science. They should remember, though, that a science park is not necessary the most effective way to become involved in industrial science and technology. A multitude of other mechanisms exist. At the same time, the discussion of the role models (Silicon Valley, Route 128 and Cambridge-UK) places their spontaneous development in sharp contrast with the artificial push experienced on most science parks. In these instances, science parks were consequences rather than causes of regional technological development.

To summarize, we have focused on a number of topics which may help explain the current differences between the expectations and the realities facing the development of science parks. Although it may sound rather sceptical, we should keep in mind the recent character of many science parks (a majority of them are less than 10 years old). This may necessitate a review of some of the statements made earlier as time goes by. However, at least some of the problems are unlikely to change with time (e.g.,the issue of professional proximity versus physical proximity).

A final remark can be made, especially with respect to many European science parks, namely the short distances on the continent. For instance, the vast majority of Belgian universities lies within a radius of about 50 kilometers of the capital of Brussels. The same remark holds for the Netherlands, and even for the industrialized parts of the UK. Thus, do we really need to emphasize physical proximity in instances where everything is already so close?

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